

# Informational Leaflet 58

1964 KVICHAK RIVER RED SALMON

(Oncorhynchus nerka) SMOLT STUDIES

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## 1964 KVICHAK RIVER RED SALMON (Oncorhynchus nerka) SMOLT STUDIES

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### I.) INTRODUCTION

The size of the red salmon (Oncorhynchus nerka) runs returning to the Kvichak River is extremely variable. Since 1956 the returns to the Kvichak have varied from a low of 562,219 fish in 1963 to a high of 22,606,500 fish in 1960. It is obvious that, in order to properly manage the fishery on a run exhibiting so much size variation from year to year, some sort of foreknowledge or prediction of total return is necessary. Also necessary is a knowledge of the factors causing this cyclic variation and what their effects are on the red salmon production from escapements of various sizes. The Kvichak River smolt outmigration project is designed to provide an index of the relative yearly abundance of red salmon smolt leaving Lake Iliamna. The project also provides data on age and size of the smolt. These data are used in predicting the size of future adult returns to the Kvichak and also add to our knowledge of the life history of red salmon in Lake Iliamna.

In 1955, the Fisheries Research Institute of the University of Washington initiated the smolt outmigration study as part of their optimum escapement studies of the Kvichak River red salmon run. From 1955 to 1960 the smolt project was under the supervision of the Fisheries Research Institute. In 1961 the Division of Commercial Fisheries, Alaska Department of Fish and Game, conducted the program and in 1962 Fisheries Research Institute conducted the smolt studies under contract to the Alaska Department of Fish and Game. The Division of Biological Research, ADF&G, was responsible for the supervision of the Kvichak smolt project in both 1963 and 1964. The Commercial Fisheries Division provided the temporary personnel and material and supervised the initial installation.

The 1964 outmigrants were the progeny of the 1961 and 1962 parent escapements. Of special interest were the Age II (fish that have spent two winters in the lake) outmigrants from the 1961 parent escapement. (Refer to Figure 8.) Parent escapements by year and adult return from 1956 and 1957 and parent escapements for 1960 and 1961 are given below:

	<u>Parent Escapement</u>	<u>Adult Return</u>		<u>Parent Escapement</u>
1956:	9,443,000	33,063,000	1960:	14,630,000
1957:	2,966,000	3,611,000	1961:	3,706,000

The 1956 production of 3.5 returning adults per spawner as compared to the 1957 production of 1.2 returning adults per spawner caused speculation that the poor production from 1957 was due to competition in the lake of the

progeny of the 1957 escapement with the progeny of the large 1956 escapement. This led to the hypothesis that it might be wasteful to allow more than a token escapement in years following a peak year. Since the relationship between the 1960 and 1961 escapements was analagous to the 1956 and 1957 escapements, the smolt outmigration in 1964 was of special interest. Only 3.4 24-hour index points of Age I (fish that have spent one winter in the lake) smolt from the 1961 escapement were captured in 1963.

In view of past variations between actual returns and predictions based on the smolt indices, it was decided that this report should incorporate a review and analysis of past smolt data.

Data and information from past reports on the Kvichak smolt programs is used in this report without footnote reference. A list of these reports is given in the bibliography.

## II.) METHODS AND PROCEDURES

The smolt indices, in order to be comparable, must be obtained in as much the same way as possible from year to year. During the first years of this study, it was felt that the majority of the smolt migrated during the darker night-time hours. Sampling throughout the day indicated that the largest outmigration occurred during the 3-hour period 2200-0100. This period was called the "index period" and sampling was restricted to this time. More recent studies have indicated that the index period alone does not adequately sample the outmigration and hence 24-hour sampling has been carried on since 1962. A standard index fishing site has been chosen approximately four miles downstream from the outlet of Lake Iliamna (Figure 1). There is a bend in the river at this point with a deep channel on one side and a sloping gravel bar on the other. A minor secondary channel leaves the main river just above the smolt site and passes downriver on the side of the island opposite the smolt site. A single fyke net with a four-foot square frame is fished at this site. The wings of the net are spread to fish a nine-foot wide section of the river. The net is fished at a depth of 3 feet 8 inches to 3 feet 10 inches. This depth is kept constant by moving the net up and down the gravel bar during the course of the season as water levels fluctuate. Once the migration has begun, the net is fished as much as possible on a 24-hour per day basis.

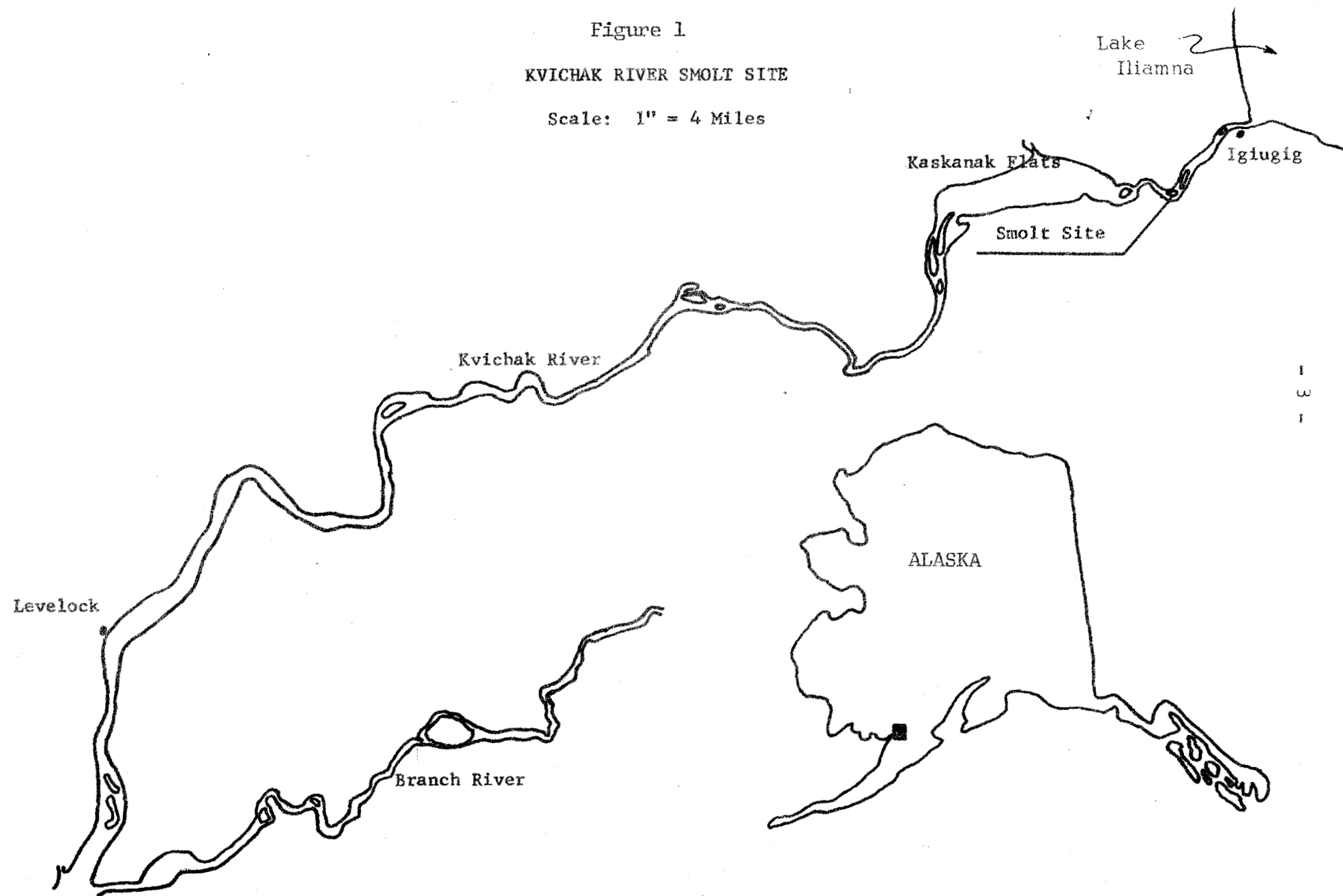
Smolt are either captured in a removable bag or "cod end" attached to the end of the net funnel or counted by means of photo-electric counters. The cod end is used mainly during periods of low migration or when it is necessary to be able to quickly remove the net from the river because of ice floes from Lake Iliamna. The cod end is periodically raised and the smolt removed. If the catch is under two pounds of smolt, they are counted individually; catches of over two pounds are weighed and the total catch estimated by counting the number of smolt in a random one-pound sample and multiplying this number by the total number of pounds in the catch.

The photo-electric counter system consists of two Veeder-Root Series A-180707 electronic counters, a heavy duty 12-volt battery, a Heathkit Model No. MP-10 power converter and photo-heads mounted in a metal tunnel which can

Figure 1

KVICHAK RIVER SMOLT SITE

Scale: 1" = 4 Miles



be attached to the net funnel in the same place the cod end usually occupies. A schematic diagram of the above apparatus is shown in Figure 2. The photo-head is made up of two light sources and two corresponding photo-electric cells mounted on opposite sides of the tunnel. Each set (cell plus light) is wired to a separate electronic counter which registers the number of times the light beam is broken by smolt passing through the tunnel. One set measures smolt passage in the upper half of the tunnel and a second set measures the smolt passage in the lower half of the tunnel. Approximately one in every seven smolt passing through the tunnel are registered, however, since this proportion varies, it is necessary to calibrate the photo-electric counter several times each day. This is accomplished by attaching the cod end to the photo-electric counter tunnel and recording the number of smolt caught per count.

The use of photo-electric counters has greatly facilitated the indexing of large smolt outmigrations. The fish do not have to be handled except during calibration periods which reduces the mortalities normally incurred when handling large numbers of fish manually with the cod end. The photo-electric counters also facilitate 24-hour indexing as long periods can be counted without continuously raising and lowering the cod end, weighing smolt, etc. thus decreasing the required number of personnel.

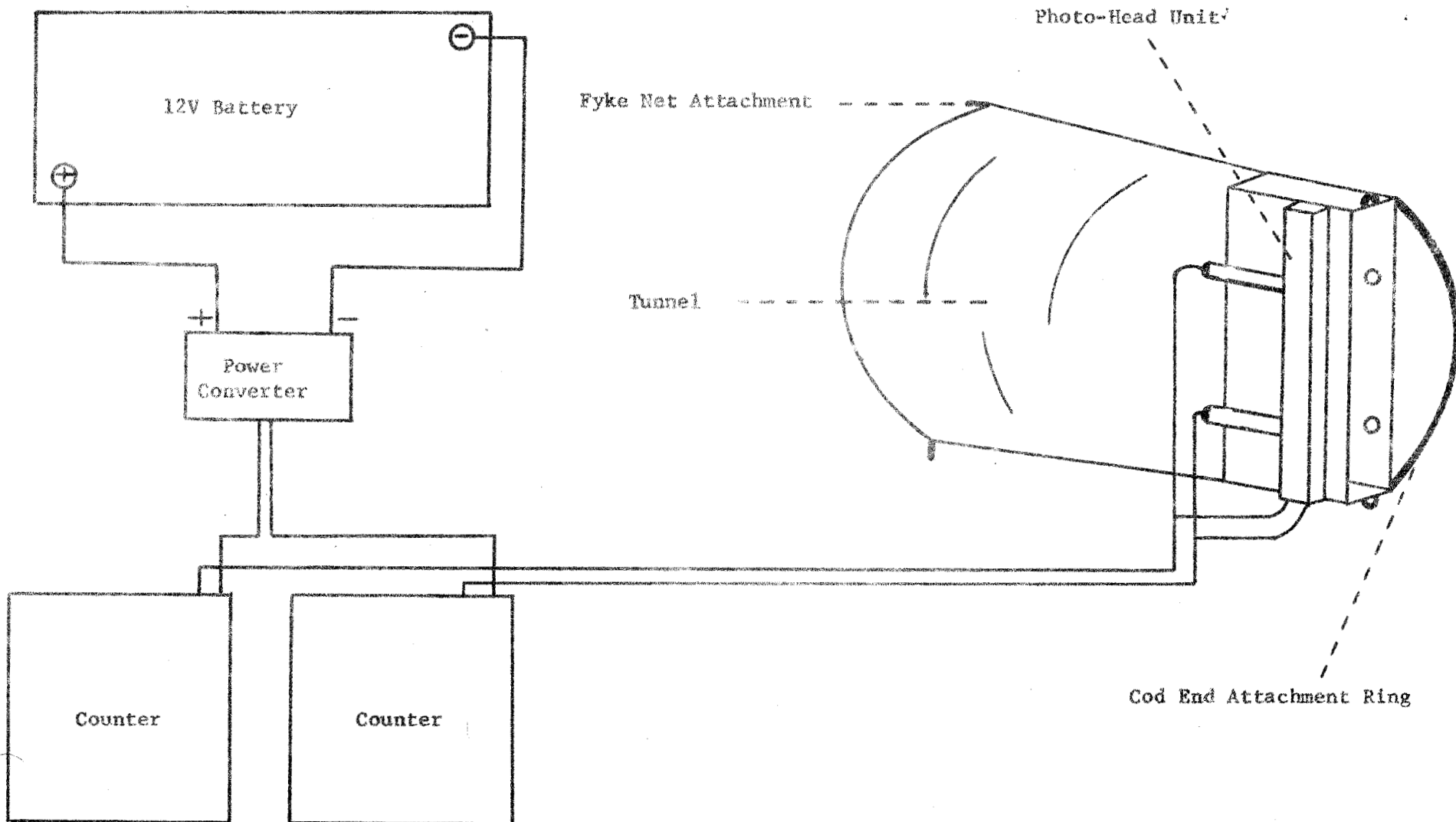
Smolt lengths were obtained by taking a random one-pound sample from catches during the index hours, 2200-0100, each day a relatively large migration occurred. The fish in this sample were anaesthetized with MS-222 (Tricaine Methanesulphonate) and measured live. Some samples were also taken from catches obtained outside the 3-hour index period.

Several times during the course of the season, a random two-pound sample of smolt was taken from the 3-hour index period catches to obtain average weights of the smolt. These smolt were anaesthetized in MS-222. The fish were then measured for length and placed in separate plastic boxes according to length (each box represented a 3-millimeter length group) up to a maximum of ten smolt per box. The boxes were covered to prevent evaporation and a wire screen was placed in each box to hold the fish off the bottom and allow them to drain. Each container was weighed with fish and again with the fish removed. The difference between the two weights gave the weight of the fish and this weight, when divided by the number of fish in the container, gave the average weight per fish in the 3-millimeter grouping. These daily weights and lengths were later weighted by their respective daily index catches to obtain average lengths and weights for the season.

There are normally only two age classes of smolt encountered in the Kvichak system, viz. Age I and Age II smolt. The Age II smolt are generally larger than the Age I fish and the majority of the fish can be separated according to age on this basis. There is, however, some overlap in size between the larger Age I fish and the smaller Age II fish. The approximate point of separation is determined by aging scales taken from measured fish periodically during the course of the migration.

Weather observations were made twice daily during the course of the out-migration. Water temperatures were taken twice daily near the lake outlet at the scow site and during the index hours at the index site.

FIGURE 2  
PHOTO-COUNTER ASSEMBLY



### III.) DISCUSSION OF THE 1964 SMOLT PROJECT

#### A.) Dates of Sampling, Interruptions Due to Ice, Water Temperatures and Climatological Data

Personnel, equipment and supplies were flown to the field camp at Igiugig on May 18. Personnel consisted of two permanent biologists and three biological aides. Fishing was begun on May 19 and was continued every day (unless ice flow prevented sampling) until midnight on June 22 at which time catches indicated that the major part of the outmigration had passed the site.

Each spring, during the latter part of May and/or the first part of June, ice floes move down the Kvichak River from Lake Iliamna. As seen from Figure 1 the smolt site is near the outlet of the lake and hence there is little dissipation of ice between the outlet and the smolt site. Ice flow past the smolt site ranges from occasional small ice chunks to ice floes that cover the entire river. A quick release mechanism has been used to attach the fyke net bridle ropes to the anchor ropes. This allows the fyke net to be quickly released when ice floes endanger the net, thus minimizing the loss of fishing time and damage to the fyke net equipment. It is impossible to operate the fyke net during the periods of extremely heavy ice flow.

A summary of interference in sampling due to ice flow is given in Table 1. Although ice interrupted index-period sampling during eleven days, heavy smolt outmigration occurred during only three of these days, viz. 6/3-4, 5-6, and 8-9. For two of the three days, at least partial sampling was possible, however the entire index period was missed on 6/8-9. Ice flow in the river completely prevented fishing on 6/12-13.

Figure 3 shows the water temperature (in degrees fahrenheit) taken during the index period (2200-0100) at the smolt site during the 1964 season. If different temperatures were obtained during a single index period, the arithmetic average was determined and used to represent the temperature for that index period. Kerns and Marriott (1963) have noted that on the basis of past data, substantial outmigrations of smolt did not occur until after the water temperature reached 36°F. This was substantiated again in 1964 as appreciable migration did not occur until after June 1 at which time the water temperature was 38°F. After June 1, water temperatures did not fall below 36°F.

Table 2 shows the beginning date of peak outmigration and the corresponding water temperatures for each year since 1955. Water temperatures at the beginning of peak outmigration have varied from 36° to 45°F, indicating that factors other than the water temperatures are also influential in causing the smolt to leave the lake and move into the river. This is further substantiated by the fact that in 1964 water temperatures rose to 37°F on May 26 and did not fall below 36°F after May 26, however very little outmigration occurred from May 26 to May 31.

General climatological and river observation data taken during the 1964 season is given in Table 3.

Table 1

INTERRUPTIONS IN SMOLT SAMPLING DUE TO ICE FLOW  
Kvichak River, 1964

<u>Date</u>	<u>Time Missed During Index Period</u>	<u>Comments</u>
5/29-30	2200-2252	Very few smolt migrating.
6/2-3	2223-2309 0012-0053	Ice flow interrupted pre-index period fishing.
6/3-4	2200-2342 2354-0100	Beginning of peak outmigration. Ice interrupted pre-index fishing.
6/5-6	2200-0013	Peak outmigration. Ice interrupted post-index period fishing.
6/8-9	2200-0100	Missed entire day. Peak migration leveling off.
6/10-11	2200-0100	Ice interrupted post-index fishing.
6/11-12	2200-2400	Substantial migration, but peak passed.
6/12-13	2200-0100	
6/13-14	2200-0100	
6/15-16	2200-2252 2308-0100	

Figure 3

WATER TEMPERATURES\* DURING RED SALMON SMOLT OUTMIGRATION  
Kvichak River, 1964

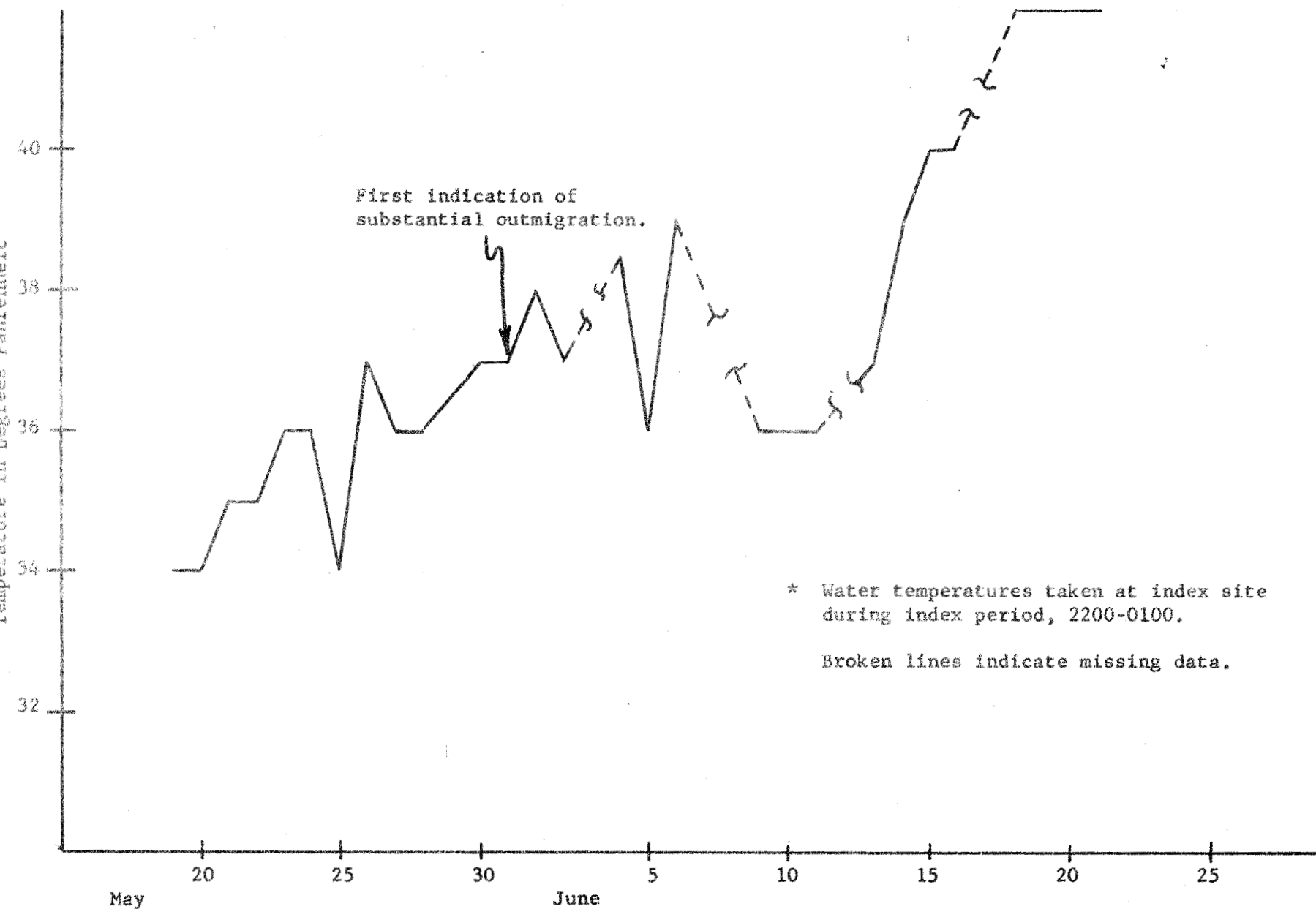


Table 2  
DATES AND WATER TEMPERATURES AT BEGINNING  
OF PEAK SMOLT OUTMIGRATIONS  
Kvichak River, 1955-64

<u>Year</u>	<u>Beginning Date of Peak Outmigration</u>	<u>Water Temperatures in Degrees Fahrenheit</u>
1955	June 4	38 <sup>0</sup>
1956	June 1	36
1957	May 28	42
1958	May 22	45
1959	May 26	42
1960	May 26	41
1961	May 23	36
1962	June 1	37
1963	May 24	36
1964	June 1	38

Table 3  
CLIMATOLOGICAL AND RIVER OBSERVATIONS<sup>1/</sup>  
Kvichak River, 1964

<u>Date</u>	<u>Air Temp.</u>		<u>Water Temp.</u>		<u>River Level</u> <u>In Inches</u>
	<u>Max.</u>	<u>Min.</u>	<u>Max.</u>	<u>Min.</u>	
5/18	--	24 <sup>0</sup> F	--	34 <sup>0</sup> F	--2/
19	--	32	34	34	3
20	46	31	37	34	3 3/4
21	38	26	36	34	4 1/2
22	44	22	37	34	3 1/4
23	52	34	36	34	5
24	42	34	37	35	5 3/4
25	50	32	37	35	5 1/2
26	54	27	38	34	5 3/4
27	64	32	40	36	5 3/4
28	56	26	38	36	6 1/2
29	60	27	42	36	6 1/2
30	72	30	39	36	6 3/4
31	79	32	39	38	7 1/4
6/ 1	80	34	40	38	7 3/4
2	69	33	38	36	8 1/2
3	53	36	37	35	9
4	72	36	42	37	9 3/4
5	70	34	40	36	11
6	70	34	40	37	11 3/4
7	70	32	42	38	12 3/4
8	54	27	40	32	13
9	62	36	36	33	14
10	64	33	37	35	15
11	64	34	36	32	18 3/4
12	65	35	36	33	13 3/4
13	71	37	38	33	18
14	70	35	39	36	21 1/2

1/ Observations were taken approximately 1/2 mile below the outlet of Lake Iliamna at the scow site.

2/ The water guage was originally set with the water level at 3 inches. A fixed bench mark is situated at the scow site and the water level measured with respect to the bench mark provides a basis of comparison for different years.

## B.) Calibration of the Photo-Electric Counters

The photo-electric counters were calibrated during a period of seven days, from June 5 through June 11, with peak outmigration occurring from June 4 through June 9. The majority of the calibrations were obtained during the index period 2200-0100, with a total of 67 separate calibrations being taken. The basic calibration data is given in Table 4.

Calibrating the photo-electric counters consisted of determining the ratio of the number of smolt passing through the fyke net to the counts indicated by the photo-electric counters. The fyke net, with the photo-electric counter and cod end attached was fished until 200 counts (during periods of heavy outmigration this was sometimes larger) were obtained, at which time the cod end was removed and the number of smolt determined. The smolt in a one-pound sample were counted and this number was multiplied by the total number of pounds in the catch to obtain the number of smolt corresponding to the 200 counts on the photo-electric counter. Table 4 shows that this ratio of smolts per count varied daily from 5.08 to 8.19 smolt per count with a geometric mean of 6.36 smolt per count. (The individual counts ranged from 4.34 to 12.10 smolt per count.)

The variation in the ratios of smolt to photo-electric count was due in part to sampling variations and variations caused by changes in the power source (the 12-volt wet cell battery). It was apparent that the efficiency of the counters decreased when the charge on the battery dropped below a certain level. The batteries were charged daily to correct this problem as much as possible.

There was no apparent relationship between the ratios of smolt per count and the time of the season during which these counts were obtained. Kerns and Marriott (1963) found definite changes in counter efficiency during different periods of the 1962 smolt season. Since this phenomena was not apparent in 1964, and since one "day" was considered to be the period from 12:00 noon of one day to 12:00 noon the following day for the purpose of calculating "daily" smolt catches, the geometric mean of the ratios (smolt per count) of the two consecutive days was used. For example, the geometric mean of the ratios for June 7 and June 8 was used to expand the photo-electric counts for the "day" from noon June 7 to noon June 8. If ratios were not available for days when the counters were used, the seasonal average of 6.36 smolt per count was used.

In order to determine whether the efficiency (measured in terms of smolt per count) of the photo-electric counter is sensitive to changes in passage rate (measured in terms of smolt per minute passing through the fyke net), the passage rate data was analyzed in two different ways. First, all of the calibration data was grouped and linear regression methods were applied, using smolt per minute as the independent variable and counts per minute as the dependent variable. The correlation coefficient  $r = 0.94$  represents a highly (i.e. 99% level) linear correlation between the smolt per minute and the counts per minute. Since a linear relationship between these two variables in the form of a line passing through the origin would indicate that the photo-electric counter is insensitive to changes in passage rate (i.e. doubling the number of smolt passing through the counter each minute would double

TABLE 4. 1964 KVICHAK SMOLT PHOTOCOUNTER CALIBRATION DATA

Date	Time Set	Fishing Time	Weight	Fish Per Pound	Total Fish	Counts	Counts Per Min. x 10 <sup>-1</sup>	Fish Per Minute	Fish Per Count	Daily Totals: $\Sigma$ Fish/ $\Sigma$ Count
6/5	0001-33	17.70	22.2 lb.	41	910	200	1.13	51.4	4.55	
	0023-45	2.67	23.0	42	966	200	7.49	361.8	4.83	
	0029-25	0.67	29.0	41	1189	200	29.85	1774.6	5.94	
	0035-15	0.67	28.8	40	1152	200	29.85	1719.4	5.76	
	0040-15	2.75	30.2	38	1148	200	7.27	417.5	5.74	
	0048-15	2.08	26.2	40	1048	200	9.62	503.8	5.24	
	0055-15	2.00	23.8	42	1000	200	10.00	500.0	5.00	
	1800-25	4.42	21.4	42	899	200	4.52	203.4	4.50	
	1810-30	12.50	21.2	41	869	200	1.60	69.5	4.34	
	1826-29	5.77	19.8	50	990	200	3.47	171.6	4.95	5.08
6/6	0015-15	1.08	26.4	44	1162	210	19.44	1075.9	5.53	
	0022-10	0.67	31.1	43	1337	200	29.85	1995.5	6.68	
	0025-12	0.38	63.4	42	2663	220	57.89	7007.9	12.10	
	0029-12	0.37	41.8	47	1965	200	54.05	5310.8	9.82	
	0033-13	0.53	49.0	44	2156	250	47.17	4067.9	8.62	
	0039-08	1.87	37.0	44	1628	220	11.76	870.6	7.40	
	0047-14	0.60	34.5	42	1449	210	35.00	2415.0	6.90	
	1734-30	5.75	27.6	46	1270	200	3.48	220.9	6.35	
	1745-13	3.28	41.8	46	1923	220	6.71	586.3	8.74	
	1752-14	4.77	22.8	48	1094	200	4.19	229.4	5.47	
	1801-11	1.32	22.6	47	1062	200	15.15	804.5	5.31	
	1806-14	5.52	24.6	47	1156	200	3.62	209.4	5.78	
	1816-16	7.40	25.4	49	1245	200	2.70	168.2	6.22	
	2201-18	42.42	23.9	43	1028	200	0.47	24.2	5.14	
	2245-14	12.07	24.1	46	1109	200	1.66	91.9	5.60	7.11
6/7	0001-14	0.62	29.9	44	1316	200	32.26	2122.6	6.58	
	0004-16	0.43	38.0	44	1672	200	46.51	3888.4	8.36	
	0007-17	0.45	33.2	44	1461	200	44.44	3246.7	7.30	
	0009-13	0.75	22.8	45	1026	200	26.67	1368.0	5.13	
	0012-14	0.52	27.4	44	1206	200	38.46	2319.2	6.03	
	0015-10	1.13	22.2	45	999	200	17.70	884.1	5.00	
	0020-10	0.77	26.5	45	1192	200	25.97	1548.1	5.96	
	0022-10	1.57	22.2	45	999	200	12.74	636.3	5.00	

TABLE 4. (Continued)

Date	Time Set	Fishing Time	Weight	Fish Per Pound	Total Fish	Counts	Counts Per Min. x 10 <sup>-1</sup>	Fish Per Minute	Fish Per Count	Daily Totals ΣFish/ΣCount
6/7	0025-10	2.57	21.8	47	1025	200	7.78	398.8	5.12	
	0032-07	0.42	19.3	46	888	200	47.62	2114.3	4.44	
	0036-10	4.08	19.2	51	979	200	4.90	240.0	4.70	
	0042-06	1.50	21.0	47	987	200	13.33	658.0	4.96	
	1327-14	6.60	28.8	47	1354	200	3.03	205.2	6.77	
	1338-23	7.03	32.0	49	1568	200	2.84	223.0	7.84	
	1438-17	1.05	50.4	46	2318	210	20.00	2207.6	11.04	
	1443-13	2.28	39.2	45	1764	200	8.77	773.7	8.82	
	1449-13	1.28	36.2	41	1484	200	15.62	1159.4	7.42	
	1455-12	5.30	39.2	47	1342	200	3.77	347.5	9.21	
	1847-12	13.63	21.4	44	942	200	1.47	69.1	4.71	
	2201-36	6.90	20.5	51	1046	200	2.90	151.6	5.23	
	2210-10	5.30	23.0	51	1173	200	3.77	221.3	5.86	
	2217-08	3.43	25.2	47	1184	200	5.83	345.2	5.92	
	2222-11	6.80	22.6	49	1107	200	2.94	162.8	5.53	
	2231-10	7.60	26.2	52	1362	200	2.63	179.2	6.81	
	2241-13	6.17	26.8	47	1260	200	3.24	204.2	6.30	
	2248-09	6.10	26.8	49	1313	200	3.28	215.2	6.56	
	2255-07	3.25	27.5	41	1128	200	6.15	347.1	5.64	6.39
6/8	0001-18	1.23	37.2	45	1674	210	17.07	1361.0	7.97	
	0004-08	1.60	28.6	47	1344	200	12.50	840.0	6.72	
	0007-05	1.02	25.6	46	1178	200	19.61	1154.9	5.89	
	0009-07	0.98	24.5	47	1152	200	20.41	1175.5	5.76	
	0012-05	2.42	29.0	49	1421	210	8.68	587.2	6.77	
	0018-06	2.07	25.4	46	1168	200	9.66	564.3	5.84	
	0022-06	2.45	24.2	52	1258	200	8.16	513.5	6.29	
	0034-11	1.30	27.2	47	1278	200	15.38	983.1	6.39	
	0037-12	0.48	24.2	51	1234	200	41.67	2570.8	6.17	
	0042-12	1.65	33.8	50	1690	200	12.12	1024.2	8.45	
	0046-11	2.82	32.0	52	1664	200	7.09	590.1	8.32	
	0050-08	4.75	18.6	50	930	200	4.21	195.8	4.65	6.61
6/9	1815-17	21.05	18.0	59	1062	200	0.95	50.5	5.31	5.31
6/10	0001-18	56.45	34.4	50	1720	210	0.37	30.5	8.19	8.19
6/11	0101-28	4.73	19.6	64	1272	200	4.23	268.9	6.36	6.36

the counts per minute), the hypothesis that the line does pass through the origin was tested. A test employing the F-statistic indicated a rejection of the hypothesis. General linear regression produced the line

$$Y = 33.7 + 0.107 X \quad (1)$$

where  $X$  = smolt per minute passing through the fyke net,  
 $Y$  = photo-electric counts per minute.

The basic data and the line given by Equation (1) are plotted in Figure 4.

The fact that Equation (1) does not pass through the origin indicates a change in the efficiency of the counters as the passage rate changes. This is further substantiated by a second method of analysis. To minimize variations in counter efficiency due to variations in power source, external temperatures and weather, etc., the calibration data was grouped as shown in Table 5 below.

Table 5

LINEAR CORRELATION BETWEEN SMOLT PER COUNT  
AND SMOLT PER MINUTE FOR PHOTO-ELECTRIC COUNTERS  
Kvichak River, 1964

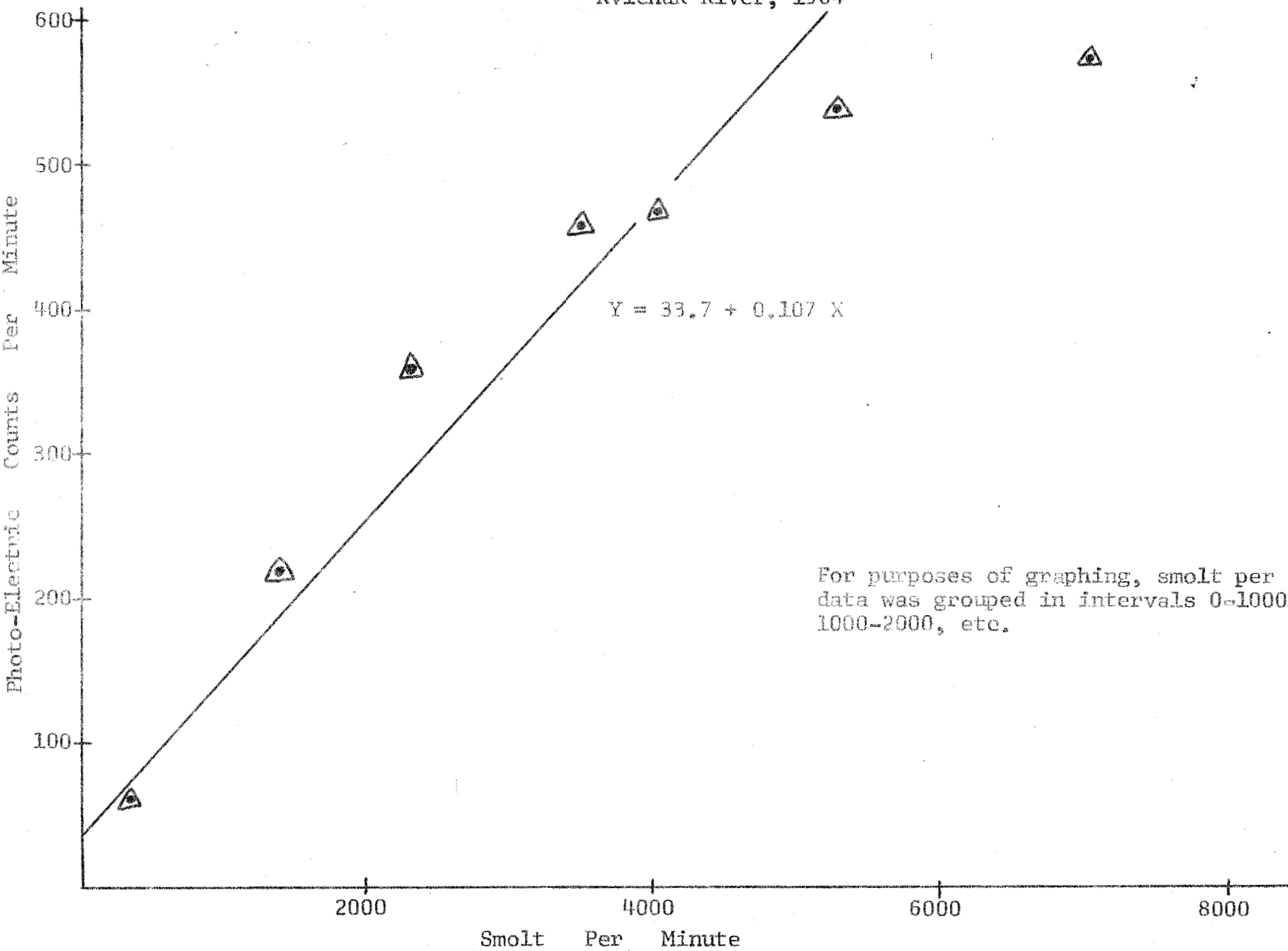
<u>Day</u>	<u>Time of Calibration</u>	<u>Correlation Coefficient</u>	<u>Level of Linear Correlation</u>
6/5	0001-0055	0.762	Significant at 95% Level
6	0015-0047	0.945	Significant at 99% Level
6	1734-2245	0.359	Not Significant at 95% Level
7	0001-0042	0.862	Significant at 99% Level
7	1327-2255	0.767	Significant at 99% Level
8	0001-0050	0.113	Not Significant at 95% Level

The data for each of these periods is plotted in Figure 5 by plotting smolt per count against smolt per minute. Since a linear relation was apparent for at least several of the groups, the linear correlation coefficient was determined for each set of data with the results being given in Table 5. For those periods for which significant linear correlation was indicated, the linear regression line was determined and is also shown in Figure 5.

This analysis indicates that as the passage rate (i.e. smolt per minute) increases the number of smolt per count registered by the photo-electric counter increases, i.e. the counter efficiency decreases. In 1964 it was

Figure 4

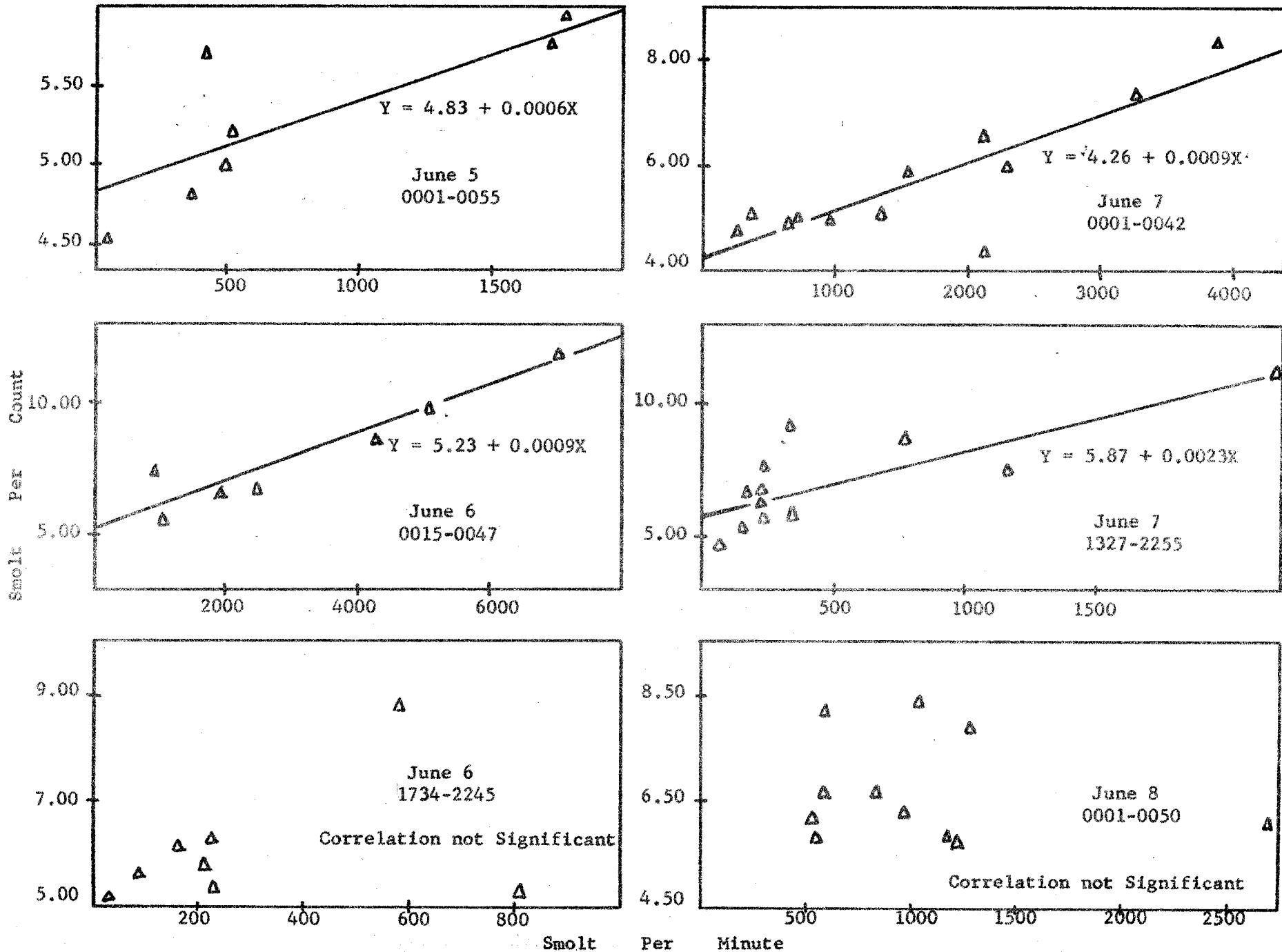
RELATION BETWEEN SMOLT PER MINUTE PASSING THROUGH THE FYKE NET  
AND COUNTS PER MINUTE REGISTERED ON THE PHOTO-ELECTRIC COUNTERS  
Kvichak River, 1964



For purposes of graphing, smolt per minute  
data was grouped in intervals 0-1000,  
1000-2000, etc.

Figure 5

RELATION BETWEEN SMOLT PER MINUTE AND SMOLT PER PHOTO-ELECTRIC COUNT



felt that because of the small variations observed (note the small slopes of the lines in Figure 5), daily averages of smolt per count would produce sufficient accuracy, however in years of very large outmigration the above results may become more important. It may be that this phenomena does not occur every year, in fact, cursory examination of the 1962 and 1963 data indicates that this linear relationship between passage rate and counter efficiency did not occur (as was the case for the third and sixth periods of Table 5). In this case, as when very small changes in counter efficiency occur, no refinement in treatment beyond the use of daily averages is warranted.

### C.) Interpolation and Total Smolt Index

In order to obtain estimates of total 24-hour smolt catches, it was necessary to interpolate for periods during which the fyke net was not fished. Interruptions in fishing were due to ice flow, changes in water level which necessitated changing the position of the fyke net, adjustments or repairs on the equipment, cleaning the fyke net, etc. Because of the relatively few smolt migrating during daytime periods (except during peak migration), it was felt that part-time sampling during these periods was sufficient. Catches during these fractional periods were then expanded to the entire period.

The noon to noon days were divided into five periods, 1200-2200, 2200-2300, 2300-2400, 0000-0100 and 0100-1200, with the three hourly periods being combined to form the index period. Smolt catches in 1964 are given in Table 6.

Two basic types of interpolation were used. First, if any part of one of the five periods listed above was fished, the catch during this period was expanded by direct proportion to obtain the catch for the entire period. A second type of interpolation was used if no part of a period was fished. Catch figures obtained for these periods are shown in parenthesis in Table 6. The following comments explain the methods of interpolation used.

- 1.) The zero catches given to missing periods were chosen for conservative estimates as visual observations of catches in periods adjacent to the missing period indicated that fish migrating during the missing periods did not substantially add to the total 1964 catch.
- 2.) If one of the three daily index hours was missed, the average catch of the other two index hours was used.
- 3.) If either of the two periods 1200-2200 or 0100-1200 were missing and the catches for the same period on the preceding and following days were available, then the average catch of these periods was used for the missing period.
- 4.) The ratio of the 2300-2400 catch on 6/3-4 to the catch for the same period on 6/4-5 was used to determine the catches for the index hours 2200-2300 and 0000-0100 on 6/3-4 from the corresponding index hour catches on 6/4-5.

TABLE 6. 1964 KVICHAK RIVER SMOLT DATA

Date	1200-2200	2200-2300	2300-0000	0000-0100	Index-Total 2200-0100	0100-1200	Total	Accumulative Total
5/19-20	0	0	0	0	0	0	0	0
20-21	(0) <sup>1/</sup>	(2)	1	3	(6)	22	(28)	28
21-22	(0)	1	0	1	2	(0)	(2)	30
22-23	0	0	0	2	2	(0)	(2)	32
23-24	(0)	0	0	5	5	(0)	(5)	37
24-25	0	0	3	4	7	(0)	(7)	44
25-26	0	0	0	13	13	66	79	123
26-27	0	3	0	8	11	11	22	145
27-28	0	0	23	8	31	(0)	(31)	176
28-29	5	0	0	3	3	(0)	(8)	184
29-30	(2)	75	72	1	148	(0)	(150)	334
30-31	0	0	35	5	40	(0)	(40)	374
5/31-6/1	0	0	80	255	335	66	401	775
6/ 1-2	2	0	170	144	314	(1763)	(2079)	2854
2-3	772	426	11,527	3089	15,042	3460	19,274	22,128
3-4	0	(1806)	6880	(1266)	(9952)	(25,952)	(35,904)	58,032
4-5	9192	21,887	83,405	15,345	120,637	48,444	178,273	236,305
5-6	72,498	(5314)	(105,596)	123,600	(234,510)	47,612	(354,620)	590,925
6-7	147,237	2756	54,764	64,101	121,621	51,172	320,030	910,955
7-8	246,198	14,578	33,216	49,209	97,003	21,752	364,953	1,275,908
8-9	(133,764)	(7391)	(17,524)	(26,348)	(51,263)	(36,926)	(221,953)	1,497,861
9-10	21,330	204	1833	3486	5523	52,099	78,952	1,576,813
10-11	27,452	(4703)	(5086)	(6776)	(16,565)	(57,667)	(101,684)	1,678,497
11-12	(24,391)	(9202)	8340	10,065	(27,607)	63,235	115,233	1,793,730
12-13	(13,216)	(4662)	(4264)	(5182)	(14,108)	(32,740)	(60,064)	1,853,794
13-14	(2040)	(122)	(189)	300	(611)	(2244)	(4895)	1,858,689
14-15	4390	3053	4706	7486	15,245	36,289	55,924	1,914,613
15-16	(2195)	16,628	4182	(10,405)	(31,215)	(28,076)	(61,486)	1,976,099
16-17	0	(7430)	8820	6039	(22,289)	19,862	42,151	2,018,250
17-18	785	(1885)	3518	252	(5655)	(18,529)	(24,969)	2,043,219
18-19	(392)	8	414	162	584	17,196	(18,172)	2,061,391
19-20	0	19	110	10	139	(0)	(139)	2,061,530
20-21	(0)	29	1	5	35	(0)	(35)	2,061,565
21-22	(0)	(7)	0	14	(21)	(0)	(21)	2,061,586
TOTALS	705,861	102,191	354,759	333,592	790,542	565,183	2,061,586	2,061,586

<sup>1/</sup> Figures appearing in parenthesis have been estimated as part or all of the period was not sampled.

- 5.) The ratio of the 0000-0100 catch on 6/5-6 to the catch for the same period on 6/6-7 was used to determine the catches for the index hours 2200-2300 and 2300-2400 on 6/5-6 from the corresponding index hour catches on 6/6-7.
- 6.) Since the entire day 6/8-9 was missed, average catches for the periods on 6/7-8 and 6/9-10 were used to obtain catches for corresponding periods on 6/8-9.
- 7.) Index hour catches on 6/10-11 were obtained by averaging the catches from the corresponding hours on 6/9-10 and 6/11-12. The catch for the period 1200-2200 on 6/11-12 was obtained by averaging catches for the same period on 6/9-10 and 6/10-11.
- 8.) The ratio of the 0000-0100 catch on 6/13-14 to the catch for the same hour on 6/14-15 was used to determine the catches for the index hours 2200-2300 and 2300-2400 on 6/13-14 from the corresponding index hour catches on 6/14-15. The catches for the periods 1200-2200 and 0100-1200 were based on average smolt per hour caught during the index period.
- 9.) Catches for periods on 6/12-13 were obtained from the averages of the catches for the corresponding periods on 6/11-12 and 6/13-14.

Visual observations of Table 6 indicated that there was no apparent relationship between the catches for the different periods. For this reason, the interpolation for missing periods was not based on seasonal ratios between the catches of the different periods, but rather on relative catches within the same day or corresponding catches for preceding and following days.

The index value assigned to a given smolt outmigration is a representation of the relative size of the yearly index catch and not an estimate of total outmigration. The large smolt outmigration of 1958 was assigned the base value of 100 index points. In 1958 the 3-hour index catch was 1,912,767 smolts, making 19, 128 smolts equivalent to one 3-hour index point. The estimated 24-hour smolt catch in 1958 was 3,333,953 smolts, making 33,340 smolt equivalent to one 24-hour index point.

The estimated daily smolt catches have already been given in Table 6. These daily catches are plotted in Figure 6. The 1964 outmigration peaked on 6/5-6, 6-7 and 7-8. Table 7 gives past inclusive dates of sampling, length of sampling period, dates of peak outmigration, length of peak outmigration and the percent of the total outmigration which occurred during the peak period of outmigration. Total estimated smolt catch for the 3-hour period 2200-0100 was 790,542, while the estimated 24-hour smolt catch was 2,061,586. In terms of 24-hour index points this is equivalent to 61.8 index points. The 3-hour index period catch was equivalent to 41.3 3-hour index points. The 3-hour index period catch represented 38% of the total 24-hour catch. Since 1955, this percentage has varied from 25% to 82% as shown in Table 8.

Figure 6

RED SALMON SMOLT FYKE NET CATCHES BY DAY\*  
Kvichak River, 1964

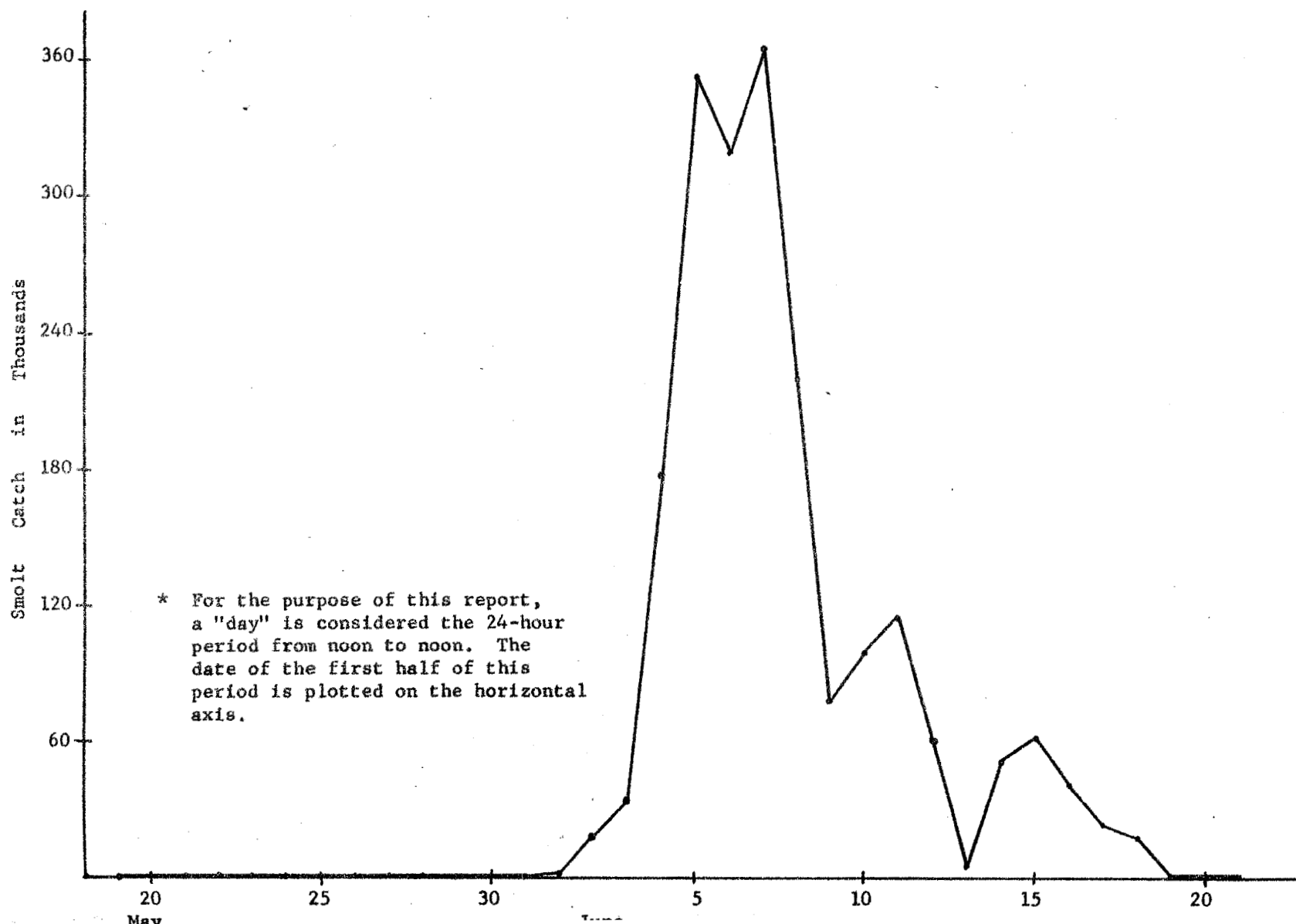


Table 7

DATES OF SAMPLING AND PEAK PERIODS OF RED SALMON SMOLT OUTMIGRATION  
Kvichak River, 1955-64

<u>Total Sampling Period</u>			<u>Period of Peak Outmigration</u>		
<u>Year</u>	<u>Date</u>	<u>Number of Days</u>	<u>Date</u>	<u>Number of Days</u>	<u>Percent of Total Catch</u>
1955	5/28-6/27	31	6/4-9	6	94%
1956	5/24-7/4	42	6/1-9 14-16	12	88
1957	5/28-7/24	58	5/28-6/6	10	84
1958	5/10-7/5	56	5/22-6/3	13	80
1959	5/23-6/28	36	5/26-6/2	8	98
1960	5/18-6/19	33	5/28-6/4	8	80
1961	5/23-6/20	29	5/23-6/2	11	81
1962	5/27-7/4	39	6/2-15	14	88
1963	5/16-6/16	32	5/24-29 6/7-9	9	86
1964	5/19-6/22	35	6/4-12	9	84
Averages		39		10	86

Table 8

PERCENT OF SMOLT OUTMIGRATION OCCURRING DURING INDEX HOURS (2200-0100)  
Kvichak River, 1955-64

<u>Year</u>	<u>Total 24-Hour Outmigration 1/</u>	<u>Percent Outmigration During Index Hours(2200-0100)</u>
1955	259,978	82.3%
1956	77,660	82.3
1957	30,907	82.3
1958	3,333,953	57.4
1959	2,863,876	57.4
1960	614,003	74.1
1961	36,154	82.3
1962	1,203,000	25.1
1963	4,229,431	32.6
1964	2,061,536	38.3
Averages	1,471,056	61.4 <sup>2/</sup>

1/ The methods used to expand the 3-hour index catches to 24-hour catches for the years 1955, 1956, 1959, 1960 and 1961 are explained in Table 11.

2/ Note that the average 61.4% migration during the index hours is probably high as the percent for three of the four years showing 82.3% was based on the fact that 82.3% of the smolt in 1957 migrated during the index hours. Sampling was not on a 24-hour basis for the years 1955, 1956, 1959, 1960 and 1961.

#### D.) Numbers, Length and Weight of Smolt by Age Group

Examination of smolt scales collected during the outmigration indicated that smolt 95 millimeters and less were Age I fish, while those over 95 millimeters in length were Age II fish. The seasonal weighted length frequency graph in Figure 7 shows this division.

Length frequency samples were weighted by their corresponding period catches to obtain the number of smolt in each millimeter grouping. These daily figures were in turn summed to yield a seasonal total for each millimeter grouping. This data is given in Table 9 and graphed in Figure 7. Using the 95 millimeter dividing point the calculated 24-hour seasonal catch of Age I and Age II fish was 458,122 and 1,603,464 smolts respectively. Similarly, the 3-hour index period catch of Age I and Age II smolt was 175,674 (22.22%) and 614,868 (77.78%) respectively.

During the early part of the season, the Age II smolt composed most, if not all, of the daily outmigration. Toward the latter part of the season, more Age I smolt began to appear, with 86% of the outmigration for the period 6/15-17 being Age I smolt. The percent of Age II smolt in the daily migration is shown in Figure 8. Whereas the Age II smolt migration peaked on 6/7-8, the Age I migration did not peak until the period 6/10-14.

Average length for each age group was obtained by summing (over the appropriate millimeter groupings) the products of the number of smolt in each millimeter grouping and the length of the fish in that grouping and dividing this sum by the total number of smolt in the appropriate age class. The average length of Age I smolt was 86.65 millimeters and average length of Age II smolt was 107.81 millimeters.

During the course of the season, 13 samples were taken to determine the average weight of smolt per three millimeter grouping. These samples were weighted according to the total index catch for the period they represented. These weighted averages were again weighted by relative number of smolt in each millimeter grouping to obtain the average weight of Age I and Age II smolt. Age I smolt had an average weight of 5.2 grams and Age II smolt averaged 9.8 grams.

Average length and weight data obtained from red salmon smolt in the Kvichak system since 1955 is summarized in Figure 9.

#### IV.) ANALYSIS AND DISCUSSION OF PAST DATA

It is generally agreed that, because of the wide variability of migration occurring outside the 3-hour index period (2200-0100), a 24-hour smolt index will provide a more accurate indication of relative smolt abundance, however, only five years (see Table 11) of actual 24-hour sampling is available. Therefore, to utilize the ten-year series of smolt data that has been collected since 1955, for the present it will be necessary to base much of our analysis on the 3-hour indices. In the past, much confusion has resulted from the fact that the basic definitions of the 3-hour and the 24-hour index points do not agree. Both the 3-hour and the 24-hour index point were defined on the

Figure 7

WEIGHTED LENGTH FREQUENCY CURVE FOR RED SALMON SMOLT  
Kvichak River, 1964

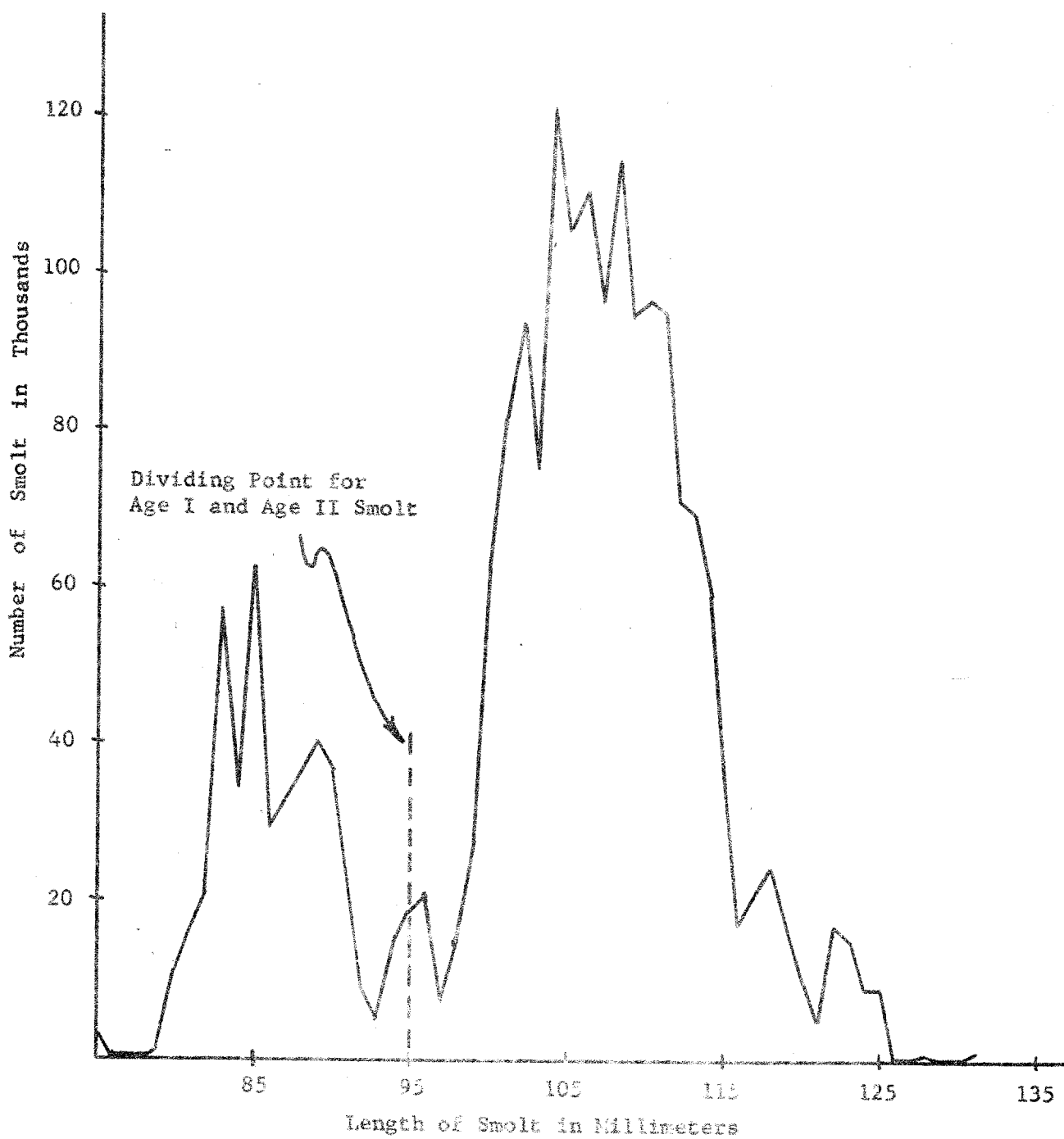


TABLE 9. RED SALMON SMOLT WEIGHTED LENGTH FREQUENCY DISTRIBUTION  
BY AGE CLASS, KVICHAK RIVER, 1964

One Check		Two Check	
Length mm.	Number	Length mm.	Number
75	2,618	96	21,262
76	190	97	7,660
77	0	98	15,022
78	0	99	27,496
79	1,254	100	62,961
80	11,248	101	81,284
81	16,485	102	93,670
82	20,552	103	75,516
83	57,609	104	121,141
84	35,003	105	105,607
85	63,040	106	110,588
86	30,067	107	96,340
87	33,448	108	114,867
88	37,638	109	94,783
89	40,627	110	96,475
90	36,617	111	95,237
91	23,650	112	71,381
92	9,244	113	69,774
93	5,329	114	59,135
94	14,792	115	34,071
95	<u>18,711</u>	116	17,651
Total	458,122	117	21,522
		118	24,758
		119	17,638
		120	10,845
Average length - 86.65 mm.		121	5,135
		122	17,672
		123	15,589
		124	8,712
		125	8,671
		126	4
		127	5
		128	131
		129	4
		130	0
		131	<u>857</u>
		Total	1,603,464
		Average length - 107.81 mm.	

Figure 8

DAILY PERCENT OF AGE II RED SALMON SMOLT IN OUTMIGRATION  
Kvichak River, 1964

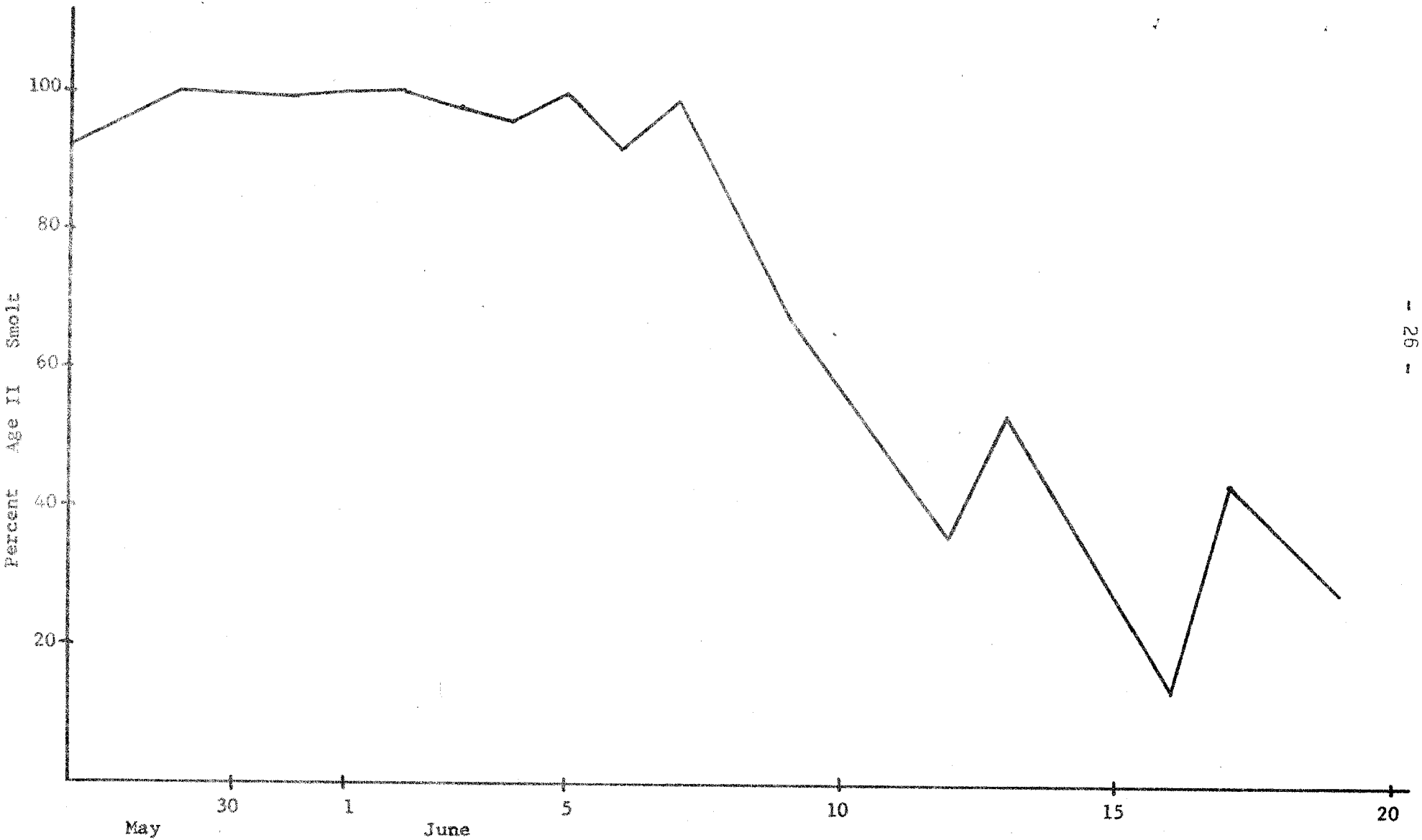


FIGURE 9. KVICHAK RIVER SMOLT PRODUCTION AND PARENT ESCAPEMENT, 1952-1964

YEAR	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964
PARENT ESCAPEMENT	6,000,000	1,348,000	241,000	251,000	9,443,000	2,965,000	535,000	680,000	14,630,000	3,706,000	2,581,000	339,000	957,000
LAKE RESIDENCE		AGE 0	AGE 0	AGE 0	AGE 0	AGE 0	AGE 0	AGE 0	AGE 0	AGE 0	AGE 0	AGE 0	AGE 0
			AGE I	AGE I	AGE I	AGE I	AGE I	AGE I	AGE I	AGE I	AGE I	AGE I	AGE I
				AGE II	AGE II	AGE II	AGE II	AGE II	AGE II	AGE II	AGE II	AGE II	AGE II
SMOLT OUTMIGRATION*				AGE II - 198,897 109 mm AGE I - 14,971 89 mm No Data	AGE II - 38,970 116 mm AGE I - 24,916 92 mm No Data	AGE II - 7,119 120 mm AGE I - 18,306 96 mm 7.3 g.	AGE II - 38,255 114 mm AGE I - 1,874,512 84 mm 4.6 g.	AGE II - 1,593,781 99 mm AGE I - 49,292 80 mm No Data	AGE II - 409,305 108 mm AGE I - 45,478 91 mm 6.3 g.	AGE II - 8,330 118 mm AGE I - 21,420 93 mm 6.8 g.	AGE II - 18,085 110 mm AGE I - 283,328 82 mm 4.3 g.	AGE II - 1,339,379 98 mm AGE I - 41,424 83 mm 4.8 g.	AGE II - 616,623 108 mm AGE I - 173,919 87 mm 5.2 g.

\* In terms of three-hour index catch. Weights and lengths are seasonal averages.

basis of the 1958 smolt catch equaling 100 index points. This meant that one 3-hour index point was equal to 19,128 smolt whereas one 24-hour index point was equal to 33,340 smolt.

To facilitate comparison of the 3-hour and 24-hour indices (as well as the 3-hour and 24-hour smolt catches) without reverting back to the original smolt catches, a single definition of an index point is given here. Henceforth, one index point is equal to 33,340 smolt. Note that this is the originally defined 24-hour index point. (The 1958 24-hour smolt catch of 3,333,953 smolt represents 100 index points.) A readjusted series of 3-hour smolt indices has been calculated by merely dividing past 3-hour (2200-0100) smolt catches by 33,340. Tables 10 and 11 present all past data in terms of smolt catches and index points for the 3-hour and 24-hour periods respectively.

The introduction to this report stated that the Kvichak smolt project was initiated to evaluate the relative smolt production from various sized escapements and to study red salmon life history. In addition, the smolt indices of abundance obtained in this study have been used to predict adult returns since they have yielded better results than the escapement-return relationships. However, the long range goal of this study should be a more complete understanding of cycle mechanisms and their implications in managing the escapement to obtain maximum yield.

Production studies in the Kvichak may be logically divided into three stages: 1.) Production of fry from eggs, 2.) production of smolt from fry, and 3.) production of adults from smolt. Simply regulating escapement to produce the most fry may not result in the maximum production of smolt if there are natural limits on the food available to these fry in the lake. If such limits exist, they should be reflected in reduced smolt size with increased parent escapements. This type of progression would mean that if a certain level of fry density is exceeded, a reduction in growth would result from which large mortalities in the lake and/or in the ocean could be incurred. Therefore, production of maximum numbers of smolt may not be a good measure of the success of escapement size regulation if these smolt are small and suffer proportionately higher ocean mortalities. In other words, our smolt studies should first determine the number of smolt produced from various sized escapements, secondly if growth is related to number of fry (or smolt), and thirdly if the size of the smolts is related to survival in the ocean. If definite relationships exist between these variables, and can be determined, it may be possible to regulate escapement sizes to maximize the yield.

A further complication is that fry may leave the lake as either Age I or Age II smolt. The relative production of adults from a given escapement may vary depending on the age of the smolts produced. In addition, the age of smolts produced may be dependent on some factor such as escapement size which can be controlled.

Generally the number of spawning adult sockeye salmon bears a poor relationship to the number of returning adult salmon. This is due in part to variable spawning, hatching and nursery conditions, variable freshwater and ocean mortality, and in the case of the Bristol Bay sockeye, the variable effect of a high seas fishery. By obtaining a measure of the production from

TABLE 10. KVICHAK RIVER 3-HOUR SMOLT CATCHES, 1955-1964

Year of Outmigration	3-Hour Index Catches				Total Number	Total <sup>1/</sup> 3-Hour Index
	Age I Number	Percent	Age II Number	Percent		
1955	14,971	7	198,897	93	213,868	6.4
1956	24,916	39	38,970	61	63,886	1.9
1957	18,306	72	7,119	28	25,425	0.8
1958	1,874,512	98	38,255	2	1,912,767	57.4
1959	49,292	3	1,593,781	97	1,643,073	49.3
1960	45,478	10	409,305	90	454,783	13.6
1961	21,420	72	8,330	28	29,750	0.9
1962	283,328	94	18,085	6	301,413	9.0
1963	41,424	3	1,339,379	97	1,380,803	41.4
1964	173,919	22	616,623	78	790,542	23.7
Ten-Year Averages	254,757	42	426,874	58	681,631	20.4

<sup>1/</sup> One Index Point = 33,340 smolt

TABLE 11. KVICHAK RIVER 24-HOUR SMOLT CATCHES, 1955-1964

Year of Outmigration	24-Hour Index Catches					
	Age I Number	Percent <sup>2/</sup>	Age II Number	Percent	Total Number	Total <sup>1/</sup> 24-Hour Index
1955	18,198	7	241,780	93	(259,978) <sup>3/</sup>	7.8
1956	30,287	39	47,373	61	(77,660) <sup>3/</sup>	2.3
1957	22,253	72	8,654	28	30,907	0.9
1958	3,267,274	98	66,679	2	3,333,953	100.0
1959	85,916	3	2,777,960	97	(2,863,876) <sup>3/</sup>	85.9
1960	61,400	10	552,603	90	(614,003) <sup>4/</sup>	18.4
1961	26,038	72	10,126	28	(36,164) <sup>3/</sup>	1.1
1962	1,130,820	94	72,180	6	1,203,000	36.1
1963	113,338	3	4,116,093	97	4,229,431	126.9
1964	458,122	22	1,603,464	78	2,061,586	61.8
Ten-Year Averages	521,365	42	949,691	58	1,471,056	44.1

<sup>1/</sup> One index point = 33,340 smolt

<sup>2/</sup> Numbers of Age I and Age II fish derived from rounded off season percentages except in 1963 and 1964 when rounded percentages were derived from numbers of smolts obtained by weighting length frequency distribution by daily catches.

<sup>3/</sup> 24-hour index catch estimated by ratios with years of actual 24-hour fishing from visual observations of smolt migration outside the three-hour index period.

<sup>4/</sup> 24-hour index catch estimated from ratios with the three-hour index period catch obtained during only two days of actual 24-hour fishing.

a given escapement at a later point in the life cycle, such as at the smolt stage, some of these variable mortalities (viz. those which occur in fresh-water) can be prevented from affecting a prediction of adult return.

Foerster (1954) found a significant negative linear correlation between the numbers of smolt and the percent return of adults, the correlation being almost entirely due to the size of the smolt. The negative correlation indicates that as the number of smolt increases the percent return of adults decreases. Furthermore, average length of the smolt was better correlated to the percentage of adult return than was the average weight of the smolt, even though there was more year to year variation in the weights than the lengths. Linear regression methods have been applied to length and weight of smolt, smolt indices, number of returning adults and percentage return of adults for the Kvichak system with the results being given in Table 12. Age I and Age II smolt data was analyzed separately.

This analysis indicates a significant inverse linear relationship between both the length and weight of the Kvichak smolt and the number of spawners in the parent escapement, with the correlation being better for Age II smolt than for Age I smolt. Although the length is better correlated than the weight to the parent escapement for Age II smolt (consistent with Foerster's findings), the opposite is true for Age I smolt. The fact that the size of the smolt is dependent on the number of parent spawners, and hence the number of fry competing in the system, indicates that the food production of the Kvichak nursery areas is not unlimited. Furthermore, it appears that the growth of Age II smolt is more density dependent than growth of Age I smolt.

Whereas the Age I smolt have varied in average length from 80 to 96 millimeters for outmigrations (3-hour index catch) ranging from 15,000 to 1,875,000 smolt, the Age II smolt average lengths have varied from 98 to 120 millimeters for outmigrations ranging from 7,000 to 1,594,000 smolt.

In Figure 10 the parent escapement and corresponding percent Age II smolt produced have been graphed for the years 1952-61. The graph of percent Age II smolt produced by year reflects the same four year cycle (for 1952-60) as the parent escapement, however it is one year out of phase with the escapements. Thus the peak years of percent Age II smolt production occur one year after the peak escapements.

Apparently, the percent production of Age II smolt is not entirely density dependent. On the basis of the peak years, the opposite appears to be true as the fry of the peak year plus one apparently encountered reduced food supply (resulting from the large fry production of the peak years) and therefore held over one more year in the lake to migrate as Age II smolt (of relatively small size). However, the 1955 parent escapement of 251,000 produced 68% Age II smolt even though it followed escapements of 241,000 (aerial survey) and 1,348,000 (aerial survey) in 1954 and 1953 respectively. The same phenomena occurred in 1959 although less pronounced than in 1955. The 1959 escapement of 680,000 produced 46% Age II smolt although it followed escapements of 535,000 and 2,965,000 in 1958 and 1957 respectively. Thus it appears that past competition in the lake is not the only factor affecting the holdover of fry for an additional year.

TABLE 12  
RELATIONSHIP OF SIZE AND NUMBER OF SMOLT TO  
PARENT ESCAPEMENT AND ADULTS PRODUCED  
Kvichak River, 1952-64

<u>Variables Related</u>	<u>Correlation Coefficient</u>	<u>Degrees of Freedom</u>	<u>Level of Significant Correlation</u>
Note: The independent variable is listed first and the dependent variable second.			
1.) Parent Escapement Age I Average Length	-0.659	9	Greater than 95%
2.) Parent Escapement Age I Average Weight	-0.783	6	"
3.) Parent Escapement Age II Average Length	-0.894	9	Greater than 99%
4.) Parent Escapement Age II Average Weight	-0.830	6	Greater than 95%
5.) Age I 3-hr. Index Age I Average Length	-0.272	9	Less than 95%
6.) Age I 3-hr. Index Age I Average Weight	-0.456	6	"
7.) Age II 3-hr. Index Age II Average Length	-0.906	9	Greater than 99%
8.) Age II 3-hr. Index Age II Average Weight	-0.863	6	"
9.) Age I 24-hr. Index Age I Average Length	-0.365	9	Less than 95%
10.) Age I 24-hr. Index Age I Average Weight	-0.600	6	"
11.) Age II 24-hr. Index Age II Average Length	-0.890	9	Greater than 99%
12.) Age II 24-hr. Index Age II Average Weight	-0.834	6	"
13.) Age I Average Length Return/ Age I Index Smolt	+0.175	6	Less than 95%
14.) Age I Average Weight Return/ Age I Index Smolt	+0.185	3	"
15.) Age I Average Length Ln(Return/ Age I Index Smolt)	+0.009	6	"

Table 12 (Continued - 1)

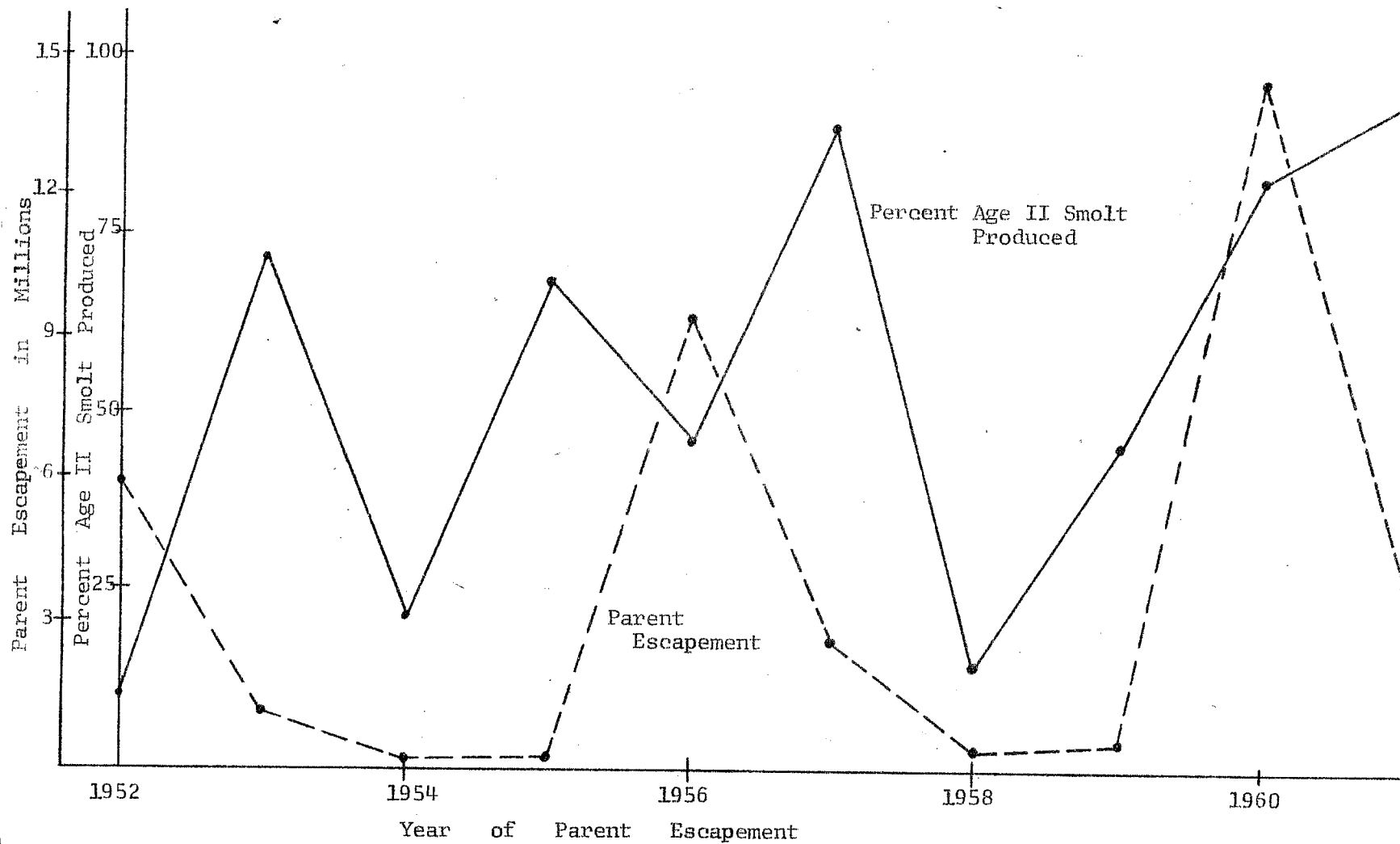
<u>Variables Related</u>	<u>Correlation Coefficient</u>	<u>Degrees of Freedom</u>	<u>Level of Significant Correlation</u>
16.) Age I Average Weight Ln(Return/Age I Index Smolt)	+0.150	3	Less than 95%
17.) Age II Average Length Return/Age II Index Smolt	+0.612	6	"
18.) Age II Average Weight Return/Age II Index Smolt	+0.785	3	"
19.) Age II Average Length Ln(Return/Age II Index Smolt)	+0.824	6	Greater than 95%
20.) Age II Average Weight Ln(Return/Age II Index Smolt)	+0.306	3	Less than 95%
21.) Age I Average Length Age II Average Length (Same Parent Year)	+0.658	8	Greater than 95%
22.) Age I Average Length Age II Average Length (Same Year of Migration)	+0.260	9	Less than 95%
23.) Age I Average Weight Age II Average Weight (Same Parent Year)	+0.613	4	Less than 95%
24.) Age I Average Weight Age II Average Weight (Same Year of Migration)	+0.843	5	Greater than 95%
25.) Age I Smolt Index Return/Age I Index Smolt	-0.518	5	Less than 95%
26.) Age I Smolt Index 2-ocean Return/Age I Index Smolt (1958 omitted)	-0.538	5	"
27.) Age I Smolt Index 3-ocean Return/Age I Index Smolt (1958 omitted)	-0.351	5	"
28.) Age I Smolt Index Number of Returning Adults (1958 omitted)	+0.214	5	"

Table 12 (Continued - 2)

<u>Variables Related</u>	<u>Correlation Coefficient</u>	<u>Degrees of Freedom</u>	<u>Level of Significant Correlation</u>
29.) Age II Smolt Index Return/Age II Index Smolt	-0.396	6	Less than 95%
30.) Age II Smolt Index Ln(Return/Age II Index Smolt)	-0.705	6	Less than 95%
Note: The 95% level of significance for r with 6 degrees of freedom is -0.707.			
31.) Age I Index Plus Age II (Same Parent Year) Index  Average Length of Age I Smolt (1958 omitted)	-0.648	8	Greater than 95%
32.) Age I Index Plus Age II (Same Parent Year) Index  Average Length of Age II Smolt (1958 omitted)	-0.869	8	Greater than 99%

Figure 10

RED SALMON PARENT ESCAPEMENT AND CORRESPONDING  
PERCENT AGE II SMOLT PRODUCED  
Kvichak River, 1952-61



Although no apparent relationship exists between the parent escapement sizes and the percent of Age II smolt produced when all of the past data is considered, the peak years, viz. 1952, 1956 and 1960, reflect a definite increase in percent of Age II smolt produced with increases in escapement size. Probably the most interesting observation to be made from Figure 10 is the relatively high 83% Age II smolt production from the 1960 parent escapement of 14.6 million as compared to 46% and 10% (approximated) Age II smolt resulting from the escapements of 9.4 and 6.0 million in 1956 and 1952 respectively. The 1960 percent production of Age II smolt was the third highest since 1952. It appears that the level of fry production from the 1960 escapement was such that intra-specific competition was sufficient to cause the fry to remain one more year in the lake. (Both the Age I and Age II smolt from the 1960 escapement were the smallest since 1955.) The fact that large percentages of Age II smolt were produced from both the peak escapement of 1960 and the escapement of 1961 indicates a return to the five-year cycle as most of the Kvichak smolt return after two years in the ocean. Thus the next peak year for the Kvichak run will be 1965.

The size of the Age II smolt is also related to the relative number of Age II smolt in the outmigration. The most apparent difference which occurs when the smolt index is substituted for the parent escapement as the independent variable, is the non-significant correlation between the size of the Age I smolt and the Age I smolt index. This may result from the fact that the parent escapement is a better indication of the number of fry (and hence intra-specific competition) in the system as the Age I index does not compensate for the fry which hold over to migrate as Age II smolt, but which were actually in competition with the Age I smolt. This is further indicated in that a significant correlation is indicated between the total number (Age I plus Age II) of smolt produced from a parent escapement and the average length of the smolt which migrate as Age I fish.

The fact that the Age II smolt size shows a better linear correlation to the Age II index than to the parent escapement may result from the fact that the last year in freshwater may (and appears to) be the most critical period for determining the size of the Age II smolt. If this is actually the case, then the Age II index which measures the abundance of only Age II smolt would be expected to be a better indicator of Age II smolt size than the parent escapement which actually indicates total smolt produced, i.e. Age I plus Age II smolt. This is further indicated by the fact that the Age II smolt average length is better correlated to the Age II index than to the total smolt (Age I plus Age II) that were in competition in the system.

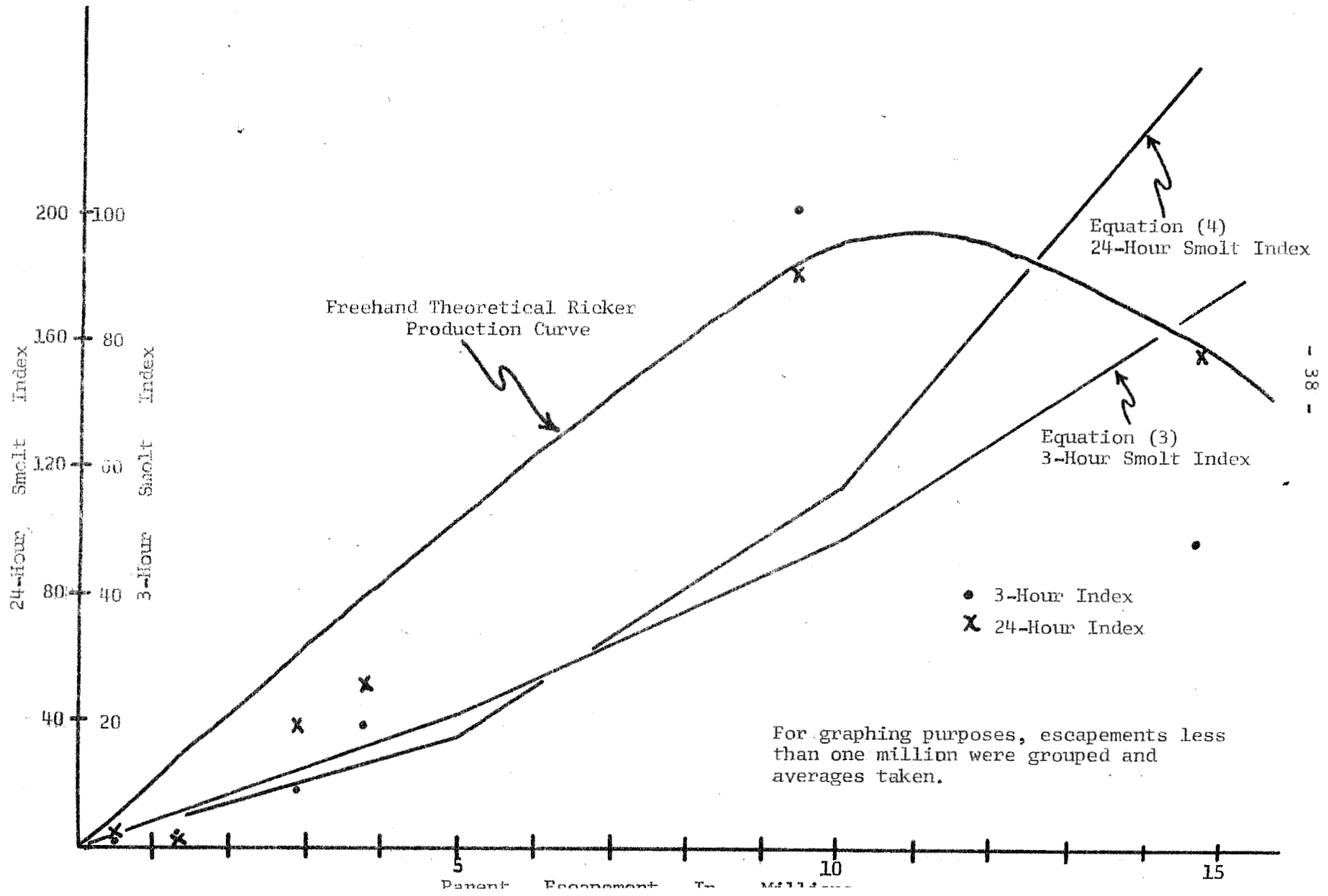
On the basis of this analysis, a better correlation exists between the average length of Age I and Age II smolt of the same parent year, than for Age I and Age II smolt from the same year of outmigration. This suggests that competition between successive generations of fry in the lake is not as significant as competition between fish of the same generation. (This is based primarily on analysis using length rather than weight of the smolt.) This would seem to indicate that the size of escapements in successive years is not as important to smolt production as the size of the escapement in a single year. This is further substantiated by referring to Table 13 from which it can be seen that 1961 had the best relative smolt production of any brood year since the cycle year of 1956 and the third best of any brood year since the smolt

TABLE 13. PARENT ESCAPEMENT AND CORRESPONDING SMOLT PRODUCTION, KVICHAK RIVER, 1952-1964

Year of Spawning	Escapement in thousands	3-Hour Index Smolt Per Spawner x 10 <sup>3</sup>			24-Hour Index Smolt Per Spawner x 10 <sup>3</sup>	
		Age I	Age II	Total	Total	
1952	6,000	---	33	---	---	
1953	1,348	11	29	40	48	
1954	241	103	30	133	162	
1955	251	73	152	225	355	
1956	9,443	199	169	368	640	
1957	2,965	17	138	155	216	
1958	535	85	16	101	133	
1959	680	32	27	59	144	
1960	14,630	19	92	111	359	
1961	3,706	11	166	177	463	
1962	2,581	67				
Averages	3,853	62	85	152	280	

Figure 11

PRODUCTION CURVES RELATING PARENT ESCAPEMENT TO INDEX SMOLTS PRODUCED  
Kvichak River, 1953-65



project was initiated in 1955. There is no indication that the nursery area was overtaxed by the 3,706,000 escapement of 1961 even though it followed an escapement of 14,630,000 in 1960.

Referring to Table 11 again it is noted that neither the Age I index nor the Age I smolt size is significantly correlated to the adult return per Age I index smolt or the natural logarithm of this variable. Although the Age II smolt index, length or weight is not significantly correlated to the adult return per Age II index smolt, the Age II smolt length and index are correlated to the natural logarithm of the adult return per Age II index smolt. Whereas increasing smolt length for Age II smolt results in higher relative return of adult salmon, increasing the number of Age II smolt migrating to sea decreases the relative return of adult salmon. This implies that the length of Age II smolt at the time of outmigration is an indication of ability to resist estuarine and marine mortalities. The rather poor overall correlation between the size and numbers of smolt and the relative return of adult salmon can probably be traced to the variability experienced in the smolt indices, the variable estuarine and marine mortality and the variable effect of a high seas fishery. This is unfortunate as the accuracy of the predictions of returning adults is adversely affected by these variabilities.

An attempt was made to relate the parent escapements to the smolts produced by means of a Ricker production curve of the form

$$S = a E e^{-b E} \quad (1)$$

where S = smolts produced (in terms of index smolt),

E = parent escapement,

a,b = constants to be determined,

e = base for natural logarithms.

In the analysis, the constant b determined was negative, yielding a production curve of the form

$$S = a E e^{b' E} \quad (2)$$

with b' positive. The curves produced using the 3-hour and 24-hour indices respectively are:

$$S = 3.42 E e^{0.036 E} \quad (3)$$

$$S = 4.77 E e^{0.086 E} \quad (4)$$

with E given in millions of fish and S in terms of index points. These equations are graphed in Figure (11). A theoretical Ricker production curve has been sketched freehand to compare with the curves given by Equations (3) and (4).

In order that Equation (2) represent a standard Ricker production curve,  $b'$  must be negative. If  $b'$  is positive, as is Equations (3) and (4), the curve represented by Equation (2) does not have a maximum value for  $S$ , i.e. increasing escapement result in increasing smolt productions, as is evident from Figure (11). The entire production data available was grouped for this analysis as there is insufficient data available to analyze production data from the same relative years of the cycle (which would be a more logical approach to this problem assuming differential production rates for the different cycle years).

On the basis of the available data and measuring production in terms of smolt produced per parent spawner (as opposed to adult return per parent spawner) it appears that reduced production resulted from the large 14.6 million escapement of 1960. The 1960 escapement produced .111 index smolt (3-hour) per spawner as compared to the average production of .152 index smolt per spawner for the years 1953-61. However, since the 1956 escapement of 9.4 million produced .368 index smolt per spawner, the highest production for the same period, it appears that the optimum escapement (in terms of optimum smolt production) for a peak year is in the range of 9-14 million spawners. At present it is difficult to evaluate the actual production of the 1960 escapement as the adult return will not be complete until 1966. The large 1960 escapement may actually have been desirable from the standpoint that it has resulted in the return to a five-year cycle for the Kvichak red salmon run.

#### V.) SUMMARY OF 1964 KVICHAK RIVER RED SALMON SMOLT STUDIES

1) During the spring of 1964, smolt studies were carried on in a manner comparable with previous years. A single fyke net was fished at the index site to obtain an index of abundance of outmigrating smolt.

2) A total of 2,061,586 smolt were estimated to have passed through the fyke net fished on a 24-hour per day basis from May 19 through June 22, with peak outmigration occurring June 5-7. Approximately 38 percent or 790,542 of these smolt were recorded during the index hours 2200-0100. In terms of index points, these are equivalent to 61.8 (24-hour) and 23.7 (3-hour) revised index points respectively.

3) Water temperatures (recorded at the index site during the index period) had risen to 37.5° F. when the first substantial outmigrations were recorded. This was consistent with past years in which substantial outmigrations did not occur until after the water temperature had reached 36°F.

4) As in the past, only two age classes were observed in the outmigrating smolt. Age I smolt from the parent escapement of 2,581,000 in 1962 comprised 22 percent of the outmigration, while Age II smolt from the parent escapement of 3,706,000 in 1961 comprised 78 percent of the outmigration.

5) Average length and weight of the 1964 Age I smolt were 86.65 millimeters and 5.2 grams respectively. Average length and weight of the

1964 Age II smolt were 107.81 millimeters and 9.8 grams respectively. The length and weight of the 1964 smolt varied slightly from the past average lengths of 87.7 and 110.0 millimeters and average weights of 5.6 and 10.4 grams for Age I and Age II smolts respectively.

6) To eliminate the confusion resulting from two different definitions of 3-hour and 24-hour index points, the previous definition of a 24-hour index point, viz.

$$33,340 \text{ smolt} = 1 \text{ index point}$$

was adopted and the original yearly 3-hour index values were adjusted accordingly.

7) Analysis of past data indicates the following:

- a) The size of the outmigrating smolt is inversely related to the number of fry of the same generation competing within the system, with a better correlation being indicated for Age II smolt.
- b) Intra-specific competition of smolt of the same generation appears to be more critical than the competition between Age I and Age II smolt from the same year of outmigration.
- c) Past data indicates that within a cycle, maximum percent Age II smolt production occurs from the brood year following the peak escapements. The large 14.6 million escapement of 1960 produced 83 percent Age II smolt in contrast to the 46 percent and 10 percent Age II smolt from the smaller peak escapements of 1956 and 1952 respectively. This has resulted in the return to a five-year cycle for the Kvichak.
- d) Relatively poor relationships exist between the size or index of the outmigrating smolt and the relative return of adult salmon.
- e) Grouping all past smolt production data from the parent escapements and fitting a curve of the form

$$S = a E e^{b' E}$$

to this data yields a positive value for  $b'$ , and hence a non-Ricker production curve.

- f) On the basis of index smolt produced per adult spawner, there is no indication that the 1961 brood year was adversely affected by the large escapement of 1960 as the relative smolt production from 1961 was third highest since 1953.

## VI.) RECOMMENDATIONS FOR FUTURE SMOLT PROJECTS

1) Early season scale samples should be sent to King Salmon, or preferably read at the smolt site to determine separation range in length between Age I and Age II smolt. This would allow concentration of sampling in the area of separation and avoid the possibility of missing this range altogether. Until the separation point is generally determined, 20-30 fish should be sampled nightly in the 80-110 millimeter range.

2) Scales should be mounted permanently between two glass slides for future use in age and growth analysis. This can be accomplished by mounting scales from 6-8 fish on the same slide and recording lengths on a form.

3) Some separate length-frequency samples should be taken during the daylight hours to settle the possibility of differential age and length composition of migrations during daylight and darkness hours.

4) A length frequency sample should be taken every day the out-migration is sampled in order that daily age composition can be determined.

5) Counts should be terminated on the hour as much as feasible to simplify calculating hourly catches.

6) Because there is some indication that some smolt migrate during the latter part of June and July, an occasional sample should be obtained, if possible, to determine age composition of these fish.

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